Emerging Evidence on COVID-19

Rapid Review on the Physiological Effects of Wearing Face Masks

Introduction

What is the evidence on the physiological changes from mask use? Is there evidence that mask use may adversely affect those with medical conditions?

Many public health organizations globally such as the World Health Organization recommend the use of face masks in public spaces to protect against COVID-19. Concerns about wearing a face mask in some settings or among people with certain medical conditions have been raised. The review focuses on the physiological effects of wearing a mask on the respiratory and cardiovascular systems and highlights were statistically significant differences were reported. The dermatological and psychological reactions to mask use are not included in this review; they may be covered as a separate topic given these are also impacts of wearing a mask (1). This rapid review summarizes literature until December 2, 2020 on the physiological changes mainly related to respiratory and cardiovascular systems from mask use that may occur in healthy populations and those with medical conditions.

Key Points

- Twenty articles were identified, which included fifteen studies investigating physiological responses arising from wearing masks, one review and four guidance documents. The majority of the studies compared the physiological effects of an N95 respirator and/or a surgical mask; only two studies included non-medical masks, see appendix for information on mask types. These were studied in different populations: healthy volunteers (n=8), health care workers (HCW) (n=2), pregnant women (n=2) and people with medical conditions (n=3).
- Healthy volunteer face mask use was assessed in eight studies. Two studies included sedentary activities only, five had a range of activity from light exercise (e.g. walking at MET 3-5) to strenuous exercise and one study evaluated the impact of wearing masks among pilots flying at 5000ft.

  Limitations:

  - The eight studies on healthy volunteers were small, a median study size of 12 (83 total healthy volunteers and 32 pilots). Studies included homogeneous groups of participants e.g. college students and/or all male. The period of study was often short and as such would not reflect the potential impact of wearing a mask for prolonged periods of time. Most studies conducted analyses to establish statistical significance between two or more measurements, these are highlighted throughout the report as significant results. The clinical significance of the reported results were rarely discussed by the authors. The findings of studies in this review are preliminary. More research is needed with larger and more representative samples to assess the generalizability of these findings.

N95 masks:

- Across six studies of healthy volunteers, N95 masks significantly increased breathing resistance and reduced air exchange volume, they caused increased heart rate and end tidal CO_2 and decreased oxygen saturation compared to no mask. Symptoms associated with these physiological changes included dyspnea (difficulty breathing), dizziness, and trouble concentrating.
- Five studies examined light to strenuous exercise in healthy volunteers. When wearing an N95 mask increased exercise intensity resulted in a more pronounced impact on some physiological parameters including increased end-tidal CO_2, and decreased minute ventilation and overall VO_{2max} compared to wearing no mask.
- One study looked at several different masks and indicated the overall physiological impact was highest for the KN95 > surgical masks > medical masks, sponge and civilian disposable masks> gauze and wearing no mask.
- In four studies, comparing the effects of N95 vs. surgical masks there was a greater physiological impact associated with N95 masks. These differences were not significant in one study, were significant for some parameters in two studies: heart rate (n=1/2 studies), minute ventilation and VO_{2max} (n=1/2) and were not reported although raw data and graphical summaries were available in the fourth study.

Surgical masks:

- Four studies (n= 63 observations) looked at surgical masks compared to no mask and they report elevated heart rate (n=3) and decreased blood oxygen saturation (n=1) compared to no mask when at rest or exercising. Surgical masks significantly reduced minute ventilation, but not VO_{2max}. At the end of the strenuous workout, end-tidal CO_2 was statistically increased with surgical mask use compared to no mask. Perceived level of exertion was higher in those who wore a surgical mask (n=2). Symptoms were not as frequently reported for surgical masks compared to N95 masks, but included dyspnea, dizziness and difficulty concentrating.
- Pilots, wearing either a surgical or non-medical cloth mask, who underwent a 90 minute 5000ft simulation exercise were found to have no difference in heart rate, end tidal CO_2, respiration rate or oxygen levels (2).

Non-medical face masks

- Two studies included non-medical face masks made of cloth, sponge, gauze or described as a civilian disposable masks. The physiological impact of different mask composition was not significantly different than surgical masks in these studies (2, 3).

- HCW studies (n=2) were conducted to understand the impact of wearing an N95 or surgical mask when executing duties related to their occupation.
    - A survey of 250 HCWs who wore surgical or N95 masks >4 hours/day reported 58.2% ($P<0.01$) had trouble breathing on exertion. Other symptoms included excessive sweating around the mouth (67.6%), skin irritation (39%) and pain behind the ear (45.2%).
    - The cerebral hemodynamic changes of donning an N95 mask were evaluated among 154 HCWs who reported headaches in association with N95 mask use. Five minutes after donning the N95 mask a significant increase in mean flow volume and end-tidal CO_2 were reported. Adding a powered air-purifying respirator (PAPR) restored these measures to normal levels.
- Pregnant women, healthy and between 13-35 weeks in gestation were studied (n=2) for the impact of N95 mask use.
    - N95 masks worn by 42 pregnant women during routine physical work (equivalent to 3 MET) showed significantly decreased tidal volume, minute ventilation and oxygen consumption, an increase in transcutaneous partial pressure CO_2, conflicting results for respiratory rate and no change in maternal heart rate, fetal heart rate or oxygen saturation compared to no mask in both studies.
    - Comparing pregnant and not pregnant women, there were no differences in the physiological impact of wearing an N95 mask (4).
- Medical conditions were assessed in three studies and included chronic obstructive pulmonary disease (COPD) (n=2), asthma (n=2) and chronic rhinitis (n=1). Information on other medical conditions was not identified.
    - In a study of 97 COPD patients using N95 masks, 7% were unable to wear the mask due to dyspnea, headache and dizziness; these tended to be individuals with more severe COPD. Those who completed the study were studied at rest and experienced increased respiratory rate, heart rate, end-tidal pCO_2 and decreased oxygen saturation compared to no mask. These differences between N95 and no mask became greater with light exercise (walking). A second study of 14 mild COPD patients reported decreased ventilatory volumes and lower FEV_1 percentage of predicted with N95 or half face mask use.
    - Among 42 people with asthma there was decreased ventilatory volumes and lower FEV_1 percentage of predicted with N95 or half face mask, the half face mask had a slightly lower impact. Similarly, the maximal voluntary ventilation was significantly reduced in three asthmatics when using a surgical mask.
    - Among 17 people with chronic rhinitis, the impact of N95 or half face mask was similar to healthy volunteers.
- Mask wearers should be cognisant of their exertion and heart rate given the studies show an increased cardio-respiratory burden of wearing any face mask and the impact increases with exercise. Heart rate should be maintained below 150 beats/min or 70% of their age max heart rate.

- Guidance Documents from Canada, United States (USA) and World Health Organization (WHO) on non-medical mask use in the community recommend that masks should not be worn by anyone who is unable to remove their mask without assistance due to risk of suffocation. This includes children under 2 years of age, and anyone who is unconscious, incapacitated, or who has trouble breathing. WHO guidelines also note masks should not be worn for source control to prevent transmission from a child under 5 with COVID-19.
- The Canadian Thoracic Society and Asthma Canada both indicate people with an underlying lung condition should be able to wear a non-medical face mask and to consult with a health care professional if this poses difficulties
- Current WHO guidelines for mask use in the community identify that masks should be removed by those who are having trouble breathing.

Overview of the Evidence

Fifteen articles pertaining to respiratory and cardiovascular physiological changes from mask use were identified and included in this review. Most were reports of quasi-experimental studies using a cross-over design where individuals acted as their own control. Most studies were in healthy populations, had small sample sizes and included homogenous populations (e.g. college students and/or male only); others included HCWs (n=1) and pregnant women (n=2). There were only three studies that specifically investigated face mask use among individuals with medical conditions: COPD (n=2), asthma (n=2). Although these studies were well-executed and had objective outcome measurements, they had low sample sizes and homogenous samples, selection bias is likely present, but could not be assessed in most studies and the findings should not be generalized without additional research. One study of HCWs was a cross-sectional survey of the self-reported impact of mask usage, the study represented HCW staff in a hospital, had a large sample size and used a questionnaire informed by formative research, however the self reported nature of results is at risk of many biases.

More research with larger sample sizes is needed for all mask types, research on the prolonged use of face masks is also needed. Thus, future research could change our understanding of the short and long term impact of wearing a face mask and who should not wear a face mask.

CONTENTS

EVIDENCE ON THE PHYSIOLOGICAL EFFECTS OF WEARING FACE MASKS

The physiological response to wearing face masks was assessed in fifteen studies on various populations: healthy volunteers, HCWs, pregnant women, instructor pilots, and persons with COPD, asthma or chronic rhinitis (Table 1). A single review, assessed to be of very low quality by AMSTAR, covers the physiological response to impeded airflow caused by face mask use and interprets this impact (5). Physiological outcomes assessed for each study were variable from study to study and are presented in the table if they were assessed. These include breathing parameters (e.g. total volume inhaled/ exhaled, breathing rate), respiratory function (e.g. oxygen and CO_2 levels), heart rate, blood pressure, and cerebral hemodynamic changes.

Eight studies using healthy volunteers included two studies on mask wearing when sedentary only, five on a range of activity from light exercise (e.g. walking at MET3-5) to strenuous exercise and included a total of 83 healthy volunteers (median study size was 12). A single study evaluated the impact of wearing masks among pilots (n=32) in a simulated flying exercise at 5000ft.

N95 masks were assessed in six studies on healthy volunteers, the masks significantly increased breathing resistance, reduced air exchange volume, heart rate and end tidal CO_2 and decreased oxygen saturation compared to no mask. Symptoms associated with the physiological changes included dyspnea (difficulty breathing), dizziness, and trouble concentrating. Five studies examined light to strenuous exercise and showed higher exercise intensity resulted in a more pronounced impact on some physiological parameters including increased end-tidal CO_2, and decreased minute ventilation and overall VO_{2max} compared to no mask.

Comparing the overall physiological impact of different masks in healthy volunteers, one study showed the impact was highest for the KN95 followed by surgical masks > medical masks, sponge and civilian disposable masks> gauze and wearing no mask. Four additional studies compared N95 to surgical masks and reported a smaller magnitude of impact where physiological outcomes were not significantly different in one study; were significant for some parameters in two studies: heart rate (1/2 studies), minute ventilation and VO_{2max} (1/2 studies) and were not reported although raw data and graphical summaries were available in the forth study.

Surgical mask use in healthy volunteers compared to no mask (n=4) report elevated heart rate (n=3) and decreased blood oxygen saturation (n=1) when at rest or exercising. Surgical masks significantly reduced minute ventilation, but not VO_{2max}. At the end of a strenuous workout end-tidal CO_2 was significantly increased with surgical masks compared to no mask. Perceived level of exertion was higher with a surgical mask (n=2) compared to no mask. Symptoms such as dyspnea, dizziness and difficulty concentrating were less frequently reported for surgical masks than N95 masks.

Non-medical face masks were only used in two studies on healthy volunteers. Pilots, wearing either a surgical or non-medical cloth mask, who underwent a 90 minute 5000ft simulation exercise were found to have no difference in heart rate, end tidal CO_2, respiration rate or oxygen levels (2). The second study compared non-medical masks made of sponge, gauze or described as a civilian disposable masks, results are only in graphs and the impact of these masks are between surgical mask and wearing no mask (3).

Healthcare workers studies aimed to understand the impact of wearing an N95 or surgical mask when executing duties related to their occupation. A survey of 250 HCWs that wore surgical or N95 masks >4 hours/day reported 58.2% (P<0.01), had trouble breathing on exertion. Other symptoms included excessive sweating around the mouth (67.6%), skin irritation (39%) and pain behind the ear (45.2%). The second study examined cerebral hemodynamic changes of donning an N95 mask among HCWs who reported headaches in association with mask use. Five minutes after donning the N95 mask a significant increase in mean flow volume and end-tidal CO_2 was reported. Adding a powered air-purifying respirator (PAPR) restored normal levels.

Healthy pregnant women between 13-35 weeks in gestation were evaluated for the physiological impact of N95 mask use. Two studies assessed the N95 during routine physical work (equivalent to 3 MET) and showed significantly decreased tidal volume, minute ventilation and oxygen consumption, an increase in transcutaneous partial pressure CO2, conflicting results for respiratory rate and no change in maternal heart rate, fetal heart rate or oxygen saturation across two studies. One of the studies also compared pregnant and not pregnant women and found no differences in the physiological impact of wearing an N95 mask (4).

Medical conditions in three studies included COPD (n=2), asthma (n=2) and chronic rhinitis (n=1). Information on other medical conditions was not identified. A study of N95 mask use in 97 COPD patients 7% were unable to wear the mask due to dyspnea, headache and dizziness, these tended to be individuals with more severe COPD. Those that completed the study had an increased respiratory rate, heart rate, end-tidal pCO_2 and decreased oxygen saturation compared to no mask. These levels were further impacted by light exercise (walking). A second study of mild COPD reported decreased ventilatory volumes and lower FEV_1 percentage of predicted with N95 or half face mask use compared to no mask. People with asthma had decreased ventilatory volumes and lower FEV_1 percentage of predicted with N95 or half face mask, the half face mask had a slightly lower impact. Similarly, the maximal voluntary ventilation was significantly reduced when using a surgical mask. No impact of the N95 or half face mask was significant for people with chronic rhinitis.

Overall weaknesses of the current evidence include small sample sizes, limited sample diversity, and physiologic assessments after only a short duration of mask wearing. This limits the generalizability of the findings and prevents extrapolation to situations when masks are worn for more than 4 hours. The clinical significance of the reported results were rarely discussed by the authors, thus while the results reported reached statistical significance, the clinical significance may be different.

Table 1. Evidence on the physiological effects of wearing N95 respirators, surgical masks or non-medical face masks (n=15)

STUDY	METHODS	KEY OUTCOMES
Healthy volunteers (n=8)		

Liu 2020 (3) Quasi-Experimental study China May 2020	12 healthy college males were given either a surgical mask, KN95 medical mask, a sponge mask, a gauze mask, or a disposable civilian mask which they wore while seated and reading for about 100 minutes. A questionnaire was then filled out and physiological measurements were taken.	• Self-reported thermal sensation vote (TSV) and symptoms such as dizziness, difficulty concentrating or thinking, listlessness and difficulty breathing, as well as dry skin and dry mouth were more pronounced with a KN95 mask than with a surgical or non-medical mask and were elevated compared to wearing no mask $p<0.05$. • Heart rate increased with wearing a mask ($p=0.04$), blood oxygen saturation decreased with wearing a mask ($p=0.048$) and mean skin temperature increased with wearing a mask ($p<0.01$). • The KN95 caused the largest change in these parameters followed by surgical masks > medical masks, sponge and civilian disposable masks> gauze and wearing no mask. Results in graphs. • There was no significant change in blood pressure (systolic < 4% change, $p=0.915$, diastolic <3% change, $p=0.529$). • This study is not generalizable due to small sample size and homogenous sample population.
Epstein 2020 (6) Quasi-Experimental study Israel Sep 2020	16 healthy male volunteers, participated in this multiple cross-over, self-control trial, using a standard cycle ergometry ramp protocol. Maximal exercise tests without a mask, with a surgical mask, and with an N95 respirator were conducted. Physiological parameters and time to exhaustion were compared. Heart rate (HR), oxygen saturation (SO_2), respiratory rate (RR), and	• Heart rate, respiratory rate, blood pressure, oxygen saturation, and time to exhaustion did not differ significantly among the different types of masks Compared to no mask at rest and at all stages of exercising the N95 mask was associated with a significant increase in end-tidal CO_2. The difference was more pronounced with increased load (more intense exercise). For surgical masks there was only a significant difference in the end tidal CO_2 in the last phase of the workout.

	end-tidal carbon dioxide ($EtCO_2$) and blood pressure were measured.	• This study is not generalizable due to small sample size and homogenous sample population.
Fikenzer 2020 (7) Quasi-Experimental study Germany Jul 2020	12 healthy males enrolled in the cross-over study which measured three incremental exertion tests, with either no mask, a surgical mask or an N95 mask (FFP2). The exertion tests were conducted on a semi-recumbent ergometer at a constant speed of 60–70 revolutions per minute. Workload increased until voluntary exhaustion occurred followed by a 10-min recovery period. Cardiac output (CO), stroke volume (SV), heart rate (HR), maximum oxygen consumption (VO_{2max}) and minute ventilation (VE) were monitored continuously at rest, during the exertion test and during recovery.	• Stroke volume and cardiac output and cardiac work did not differ significantly when wearing no mask a surgical mask or an N95 mask ($p>0.05$). • There was a marked effect on pulmonary parameters: Compared to no mask, minute ventilation was reduced with a surgical mask by −12.0±12.6% and with an N95 mask by −23.1±13.6%. • The VO_{2max} was significantly decreased with the N95 mask compared to both the surgical mask and no mask. The difference between the surgical mask and no mask was borderline. • This study is not generalizable due to small sample size and homogenous sample population.
Li 2005 (8) Quasi-Experimental study Hong Kong May 2005	10 healthy participants were enrolled in this cross-over trial. They performed intermittent exercise (at three low to moderate workloads) on a treadmill in a climate chamber wearing an N95 or surgical mask with and without nano-functional treatments (a treatment that repels water and has been shown to inactivate bacteria). Temperature, heart rate and blood pressure were measured.	• Differences between nano-treated and untreated N95 and surgical masks were not significant. • Average heart rate was significantly higher for those wearing an N95 mask compared to a surgical mask. • Increased intensity of exercise equated to a more pronounced difference in heart rate between mask types. • The humidity and temperature inside the nano-treated and untreated surgical masks were lower than for both N95 mask ($P=0.000$).

		• Symptoms of fatigue, dyspnea and overall discomfort were significantly worse for N95 masks. • This study is not generalizable due to small sample size and homogenous sample population.
Wong 2020 (9) Quasi-Experimental study Hong Kong Oct 2020	23 healthy volunteers of various sporting backgrounds participated in a case-crossover study where they underwent graded treadmill walking at 4km/hr for 6 minutes with and without a surgical mask on to investigate the physiological effect (heart rate and perceived exertion measured on a scale from 6 to 20) during moderate exercise.	• Surgical masks elevated heart rate when wearing the face mask during exercise compared to without (128.4 +/- 13.2 vs. 124.4 +/- 12.8 beats per minute) and participants reported a higher perceived level of exertion starting after 3 minutes of exercise (12.7 +/- 2.1 vs. 10.8 +/- 2.2). Results extracted for 6 minutes of exercise. • The author suggests that exercising with face masks at a submaximal level induces higher physiological responses. This may be due to restricted ventilation, heavier breathing, and sympathetic responses. • Due to increased cardio-respiratory burden from masked exercise the authors suggest that mask wearers be cognisant of their exertion and heart rate taking care not to exceed 150 beats/min or 70% of their age-predicted max heart rate. • This study is not generalizable due to small sample size.
Morris (2020) (10) Quasi-experimental study Denmark* 2020*	A cross-over trial with 8 male participants was conducted to evaluate the impact of a KN95 respirator when worn in 40°C and 20% humidity during light exercise of 5 MET for 45 minutes. Cognitive and fine-motor performances were assessed using tests previously demonstrated to	• Dyspnea was not significantly different at rest, but with exercise there was significantly more dyspnea in the KN95 group 51.3% (27.6) vs the no mask group 21.4% (14.5), < 0.001. • Results for no mask – KN95 mask body temperature measurements were not significantly different.

	be highly sensitive and reliable at detecting heat-related decrements in cognitive performance, including dehydration, and radiation. Dyspnea was measured using the Borg breathlessness scale.	• Other cognitive and fine motor outcomes were not significantly different for no mask vs. KN95 mask. • This study is not generalizable due to small sample size and homogenous sample population.
Dattel 2020 (2) Quasi-Experimental study USA Jul 2020	This study explored the effects of cloth face masks (composition not described) or surgical face masks. 32 instructor pilots were studied in a normobaric flight chamber wearing either a cloth mask or a surgical face mask. Measurements on CO_2, heart rate, respiration rate, and oxygen saturation were taken over a 90 minutes period.	• Instructor pilots reported comfort issues, fatigue, and restriction of movement from wearing face masks. • No differences in CO_2, heart rate, respiration rate, or oxygen level were found between the cloth mask and surgical mask after a 90 minute simulated flight at 5000ft. • This study is not generalizable due to small sample size.
Lee 2011 (11) Quasi-experimental study Singapore* 2010*	14 healthy adults participated in a study of breathing resistance caused by N95 respirators (3M 8210). Breathing resistance was measured for inspiration and expiration and total volume (l per 30s) were measured with and without an N95 respirator.	• Breathing resistance was a mean of 126% inspiratory and 122% expiratory flow resistance with the use of N95 respirators. • There was an average reduction of 37% in air exchange volume with the use of N95 respirators. • This study is not generalizable due to small sample size.
Healthcare Workers (n=2)		
Purushothaman 2020 (12) Cross-sectional study India Jul 2020	A survey was completed by 250 HCWs without comorbidities at a tertiary hospital who consistently wore either surgical masks or N95 respirators for a minimum of 4h/day. Data was collected in a self-reported questionnaire that was developed with formative research, but not pretested.	This study does not distinguish outcomes by surgical mask or N95 respirator. • 58.2% of HCWs indicated they experienced trouble breathing on exertion ($p<0.001$). No additional information on what is meant by exertion was provided. • Participants self-reported a range of discomfort, some common complaints were; excessive sweating around the mouth

		(67.6%), acne (56.0%) skin irritation (39%), and pain behind ear 45.2%.
Bharatendu 2020 (13) Quasi-Experimental study Singapore Feb-Apr 2020	154 HCWs seeking medical attention for headaches related to PPE use were studied; 25% had migraines and 80% indicated the headaches were *de novo* after using the N95 mask. Transcranial Doppler (TCD) monitoring of middle cerebral artery was performed using two validated measurements mean flow velocity (MFV), pulsatility index (PI) and end-tidal carbon-dioxide (ET-CO_2) pressure, which were recorded prior to donning the N95 respirator and five minutes after. N95 (3M® N95 respirator mask) was evaluated with and without a powered air-purifying respirator (PAPR, 3M® Versaflo® TR-300 series).	• Donning of a N95 respirator resulted in significant increase in mean flow volume, relative change 12.3% (SD 29.8, p<0.001), decrease in pulsatility index relative change 13.3% (SD 11.3, p<0.001) and end-tidal carbon dioxide levels were significantly elevated, an increase of, 3.1 mmHg (SD 1.2) in the N95 mask compared to no mask. • 24 participants used a PAPR and results indicate no difference in the mean flow volume, pulsatility index or end-tidal carbon dioxide levels within 5 minutes of donning the respirator compared to wearing no mask. Thus, powered air-purifying respirator restores N95 mask induced cerebral hemodynamic changes. • Given measurements were taken at 5 minutes, it is unknown if the changes are sustained or corrected by autoregulation.
Pregnant women (n=2)		
Tong 2015 (14) Quasi-Experimental study Singapore Sep 2011	Phase I assessed volume of O_2 uptake (VO_2) in 8 pregnant health care workers while performing simulated nursing tasks. Phase 2 compared the use of N95 masks to no masks in 20 pregnant women (27-32 weeks gestation) during two 15-minute exercise cycles on a treadmill at 3 METS (which was equivalent to the normal moderate work of a HCW recorded in phase 1).	Breathing through a N95 mask compared with no mask resulted in: • A significantly lower tidal volume (TV) at rest -0.15L (95%CI: -0/23- -0.08L) and during exercise -0.21L (-0.32- -0.10L), overall a ~23% decrease. • A significantly lowered minute ventilation (VE) by 5.55L (95%CI −7.58 % - −3.51) which is ~ 25.8% lower. • No significant change in breathing frequency with the N95 mask.

	In both Phases the women wore a tight fitting Hans Rudolph respirator mask that had an outlet that was either open to air or covered by N95 mask materials. And measurements included volumes of oxygen (VO_2) and carbon dioxide (VCO_2) tidal volume (TV), minute ventilation (VE), forced expired O_2 (FeO_2), and CO_2 concentrations.	• Significant reductions of forced expired O_2 concentration (FeO_2) -0.54% (-0.70 - -0.38) during exercise. • Significant elevations forced expired CO_2 concentration ($FeCO_2$) during exercise 0.30% (0.18, 0.42) and in the pre-exercise and post-exercise periods. • Pulmonary gas exchange: Significantly lower VO_2 by 13.8 % and VCO_2 by 17.7 % were reported. • There were no differences in the maternal or fetal heart rate, oxygen saturation or rating of perceived exertion with the N95 mask. • This study is not generalizable due to small sample size and short duration of exercise.
Roberge 2014 (4) Controlled Experiment USA Oct 2014	Controlled study of 22 pregnant (13-35 weeks) and 22 non-pregnant healthy women to determine if there is a difference in the physiological and subjective effects of wearing an N95 mask (filtering face piece respirator, FFR). Respiratory rate, chest wall skin temperature, maternal and fetal heart rate, pulse-derived oxygen saturation (SpO_2). Borg rating of perceived exertion scale 6-20. Measurements were taken with and without wearing an N95 mask during exercise and postural sedentary activities over a 1 hour period.	• Overall N95 use significantly decreased respiratory rate, a minor difference, mean 0.94 (95%CI: 0.1-2.2) breaths/min and transcutaneous partial pressure of carbon dioxide ($PtcCO_2$) increased over time during exercise for all women due to re-breathing of higher CO_2 levels generated during exercise. • There were no significant differences in measured physiological and subjective responses in pregnant women compared with non-pregnant women wearing N95 masks for 1 hour during exercise and sedentary activities. • There was no significant effect on fetal heart rate. • This study is not generalizable due to small sample size.
People with chronic conditions (n=3)		

Kyung 2020 (15) Quasi-Experimental study South Korea Mar-May 2015	97 patients with varying severity of COPD were monitored for symptoms and physiologic variables during a 10-min rest period and 6-min walking test while wearing an N95 face mask. Patients were 19-80 yrs, could walk unassisted, were not on long term oxygen therapy and did not have a history of recent hospitalization. Measurements included breathing frequency, dyspnea, heart rate, S_{pO2}, blood pressure and a symptom questionnaire that included modified Medical Research Council dyspnea scale score. Severity of air-flow obstruction in COPD was measured by using post bronchodilator FEV_1, 31 subjects had a $FEV_1 < 50\%$ at baseline.	• 7/97 subjects failed to wear the N95 mask for the entire test. A modified Medical Research Council dyspnea scale score ≥ 3 (odds ratio 167, 95% CI 8.4 to >999.9; $P = .008$) or a $FEV_1 < 30\%$ (odds ratio 163, 95% CI 7.4 to >999.9; $P = .001$) was associated with an inability to continue wearing an N95 mask. Symptoms in this group were more pronounced and included dyspnea, dizziness and headache. Among the group that completed the test: • At rest breathing frequency was increased wearing an N95 mask (20.7 breaths /min) vs. no mask (19.7). • End tidal PCO_2 (25.7 mm Hg) wearing an N95 mask vs. no mask (24.8). • S_{pO2} levels were lower with an N95 mask (96.0%) vs. no mask (96.4%). • After 6 minutes of walking, significant differences were found with heart rate (92.4 vs. 87.7), breathing frequency (25.7 vs. 23.3 breaths/min), end tidal PCO_2 (35.5 vs. 34.0 mm Hg) was higher and S_{pO2} levels were (93.0 vs. 93.8 %) lower in those with an N95 mask vs. no mask. • The authors stated that COPD patients should be warned to remove the N95 mask immediately with the onset of dyspnea, headache, or dizziness.
Harber 2010 (16) Controlled experiment USA 2010	97 individuals, 42 with asthma, 14 mild COPD, 17 chronic rhinitis and 24 healthy individuals' respiratory effects of using a dual cartridge half face mask or a N95 respirator while doing work tasks.	• Compared with an N95, tidal volume, minute ventilation and respiratory rate were slightly lower with half mask, but this may not be of clinical significance. No consistent effect was noted for volumes for COPD or asthma.

	Respiratory outcomes included tidal volume, minute ventilation, inspiratory/ expiratory time, duty cycle and flow rates.	• COPD had prolonged time to reach peak expiratory flow rate. • Those with rhinitis performed better than COPD and asthma. • Age was not a factor. • Those with asthma or mild COPD had a lower FEV_1 percentage of predicted, which was associated with ventilator volume. • This study is not generalizable due to small sample size.
Ciocan 2020 (17) Quasi-Experimental study Italy Oct 2020	10 HCWs including 3 with asthma and 3 current smokers were included in this cross-over trial. They wore a 4 layer surgical mask (AFLUID) during 4 hours of mild-moderate usual working activities and their respiratory function was monitored. A Respiratory Functional Test (RFT) was performed at three time periods and Arterial Blood Gas (ABG) samples were taken before the first and third RFT.	• Compared to no mask, Maximal Voluntary Ventilation (MVV) was reduced with a 4-layer mask (p=0.002) and remained low even during activity (p=0.041). • No significant variations in observed RFT and ABG parameters were reported although the study did not have sufficient power to detect differences. • This study is not generalizable due to small sample size.

* Location or date of study was estimated based on author affiliations and / or publication date. HCW= healthcare worker

GUIDANCE ON FACE MASK USE IN THE GENERAL POPULATION

Key guidance from Canada, the USA and WHO were identified and examined for recommendations on mask use for those with chronic medical conditions and general use in the community (Table 2).

- The Canadian Thoracic Society and Asthma Canada both indicate people with an underlying lung condition should be able to wear a non-medical face mask. However, for those that have trouble wearing a mask it is suggested to work with a healthcare provider to find a solution or avoid situations where you need a mask as much as possible to minimise your risk (18).

- The WHO's newest guidance recommends that face masks should not be worn for source control to prevent transmission from a child under 5 with COVID-19 (19). They do not specifically address if children 2-5 years old should wear a mask for protection. All guidance states children under 2 years old should not wear a mask.

Guidance from Canada (20), the USA (21) and WHO (19) state that masks should not be required for anyone who is unable to remove their mask without assistance, including children under two years old, and anyone who has trouble breathing, is unconscious, or is incapacitated due to the risk of suffocation.

- It is also suggested that people with certain disabilities or small children may be unable to wear their mask properly and thus should not wear a mask (20, 21).

Table 2. Guidance on face mask use for those with medical conditions and the general public (n=5)

STUDY	METHODS	KEY OUTCOMES
World Health Organization (19) Guidance document Switzerland Dec 2020	This is an update to WHO June 5 guidance on mask use and covers: • mask management; • SARS-CoV-2 transmission; • masking in health facilities in areas with community clusters and sporadic transmission; • mask use by the public in areas with community and cluster transmission; • alternatives to non-medical masks for the public; • exhalation valves on respirators and non-medical masks; • mask use during vigorous intensity physical activity; • Essential parameters to be considered when manufacturing non-medical masks (Annex).	• Face mask use should be part of a layered approach to public health interventions. • Masks can be for protection or source control. (Wear a medical mask if you suspect you have COVID-19). • Appropriate use, storage and cleaning guidelines are presented. • Children under 5 should not wear a mask for source control. Use of masks in older children are based on local factors and those over 12 years old should follow guidelines for adults. • Manufacturing non-medical masks: 3 layers with a hydrophilic inner layer, a hydrophobic outer layer and a hydrophobic middle layer that enhances filtration. • Exhalation valves are discouraged.
Canada.ca (20) Guidance document	Guidance on the use of non-medical masks to prevent the	• Non-medical masks protect the person wearing it and others from the spread of COVID-19.

Canada Nov 2020	spread of COVID-19 in the community. • Mask mandates • Composition of non-medical masks • Use of mask filters • Application, cleaning and storage • Children • Safety • Hearing impaired • Face shields, neck gaiters, exhalation valves	• Mandatory mask policies are put in place depending on the local spread of COVID-19. • Non-medical masks should be 3 layers, two layers of tightly woven fabric and a middle layer with filtration properties e.g. non-woven polypropylene fabric. Masks should fit snugly to the face covering the nose and mouth, but still be breathable. • Non-woven polypropylene fabric is readily available (e.g. craft fabric, interfacing or reusable shopping bags). Disposable mask filters may also be used. • Children under 2 should not wear a mask. Between 2-5 yrs mask wearing should be supervised. • Avoid stigmatization of people who cannot wear a mask due to illness or disability.
Centers for Disease Control and Prevention 2020 (21) Guidance document USA Nov 2020	Considerations for wearing masks, type not specified, to help slow the spread of COVID-19 are provided. Topics include: 1) Evidence for effectiveness of masks 2) Who should and shouldn't wear a mask 3) Difference between types of masks 4) Other types of face protection	• Face masks should not be worn by children under the age of 2 years old, anyone who has trouble breathing, and anyone who is unconscious, incapacitated, or unable to remove their mask without assistance. • Individuals with certain disabilities or children who cannot wear a mask properly should not wear one. • Most people with underlying medical conditions can and should wear a mask. Discuss with your healthcare provider if you have concerns. • Wearing a cloth mask does not raise the carbon dioxide (CO_2) level in the air you breathe.

		• Medical masks and N-95 respirators should not be used as they should be conserved for healthcare workers. • Face shields or goggles are not a substitute for masks. • The most effective cloth masks are breathable, have two-three layers, and are made of tightly woven fabrics such as cotton and cotton blends. • Those who rely on lip-reading to communicate (those that are deaf, hard of hearing, or who care for those who are hearing impaired) may be unable to wear cloth face coverings. CDC recommends a clear face covering, relying on written communication, or decreasing background noise while communicating.
Bhutani (2020) (18) Guidance document Canada July 2020	This is a guidance and position statement from the Canadian Thoracic Society on the use of face masks by the public during the SARS-CoV-2 pandemic.	• The Canadian Thoracic Society supports the recommendation from the Public Health Agency of Canada to wear a non-medical face mask in the community when it is not possible to consistently maintain a 2-meter physical distance from others. • There is no evidence that wearing a non-medical face mask will exacerbate an underlying lung condition. • Wearing a face mask alone will not prevent the spread of COVID-19 and should be complemented with other recommended public health measures such as increased hand hygiene and physical distancing. • For those experiencing challenges with wearing a mask, it is recommended they speak with their health care provider to

		develop strategies to be able to wear a face mask. If despite best efforts, wearing a mask is not possible then individuals should avoid or minimize circumstances where physical distancing is not possible.
Asthma Canada (22) Guidance document Canada 2020	Asthma Canada issued this guidance to people with asthma to address concerns related to mask use and COVID-19.	Recommendations given for people with asthma: • Masks come in different styles and material; select a mask that is most comfortable for you. • Test the mask at home to get used to how it feels. • If you cannot wear a mask without experiencing breathing issues, do not wear a mask. Instead practice 2 meter distancing and minimize time spent around people from outside your household. • Consult with your healthcare professional to go over your asthma action plan and explore other options to protect yourself.

Methods

A daily scan of the literature (published and pre-published) is conducted by the Knowledge Synthesis team in the Emerging Science Group, Public Health Agency of Canada. The scan has compiled COVID-19 literature since the beginning of the outbreak and is updated daily. Searches to retrieve relevant COVID-19 literature are conducted in Pubmed, Scopus, BioRxiv, MedRxiv, ArXiv, SSRN, Research Square, and COVID-19 information centers run by Lancet, BMJ, Elsevier, Nature and Wiley. The cumulative scan results are maintained in a Refworks database and an excel list that can be searched. Details on this search strategy are available upon request. From this database and excel list, article titles and summaries will be systematically searched for the following key words: mask* OR (face AND cover*). An additional search for guidance documents and supporting evidence on persons who should not wear a mask focused on Canada and key health organizations was conducted using a snowball technique and targeting country websites. Each potentially relevant reference was analyzed to confirm its relevance and data was extracted into the review. This review contains research published up until December 2, 2020.

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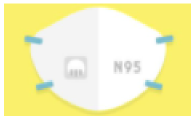
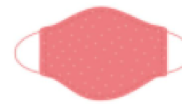
APPENDIX: TYPES OF FACE MASKS

The NCCEH blog post on masking during the COVID-19 pandemic (October 27, 2020) describes the different mask types and includes the following figure on types of masks.

	Respirator	Surgical or procedure mask	Non-medical cloth mask
			
Types	N95, 99, 100 (US, Canada), FFP2 or FFP3 (EU). Various styles including cup, flat-fold and duckbill. May also include an exhalation valve.	Typically a 3-layer laminate structure that can include a combination of non-woven air-laid paper and polypropylene.[3]	Wide variability in fabric, number of layers and design with 2-layer cotton being a common design.
Use	For use in environments where exposure to aerosols is likely. Protect against most particles (e.g., N95 block 95% of particles and provide some splash and spray protection). Medical grade N95s are tested for resistance to fluids including blood, but commercial grade are not.	For use in routine care to reduce inward and outward transfer of respiratory droplets. Filter particles > 20 µm diameter and some finer droplet nuclei.[4] Block blood and infectious materials from contact with oral, nasal and skin area. Effective against splash and sprays.	For use by the public in non-healthcare settings as source control to reduce respiratory emissions from the wearer and to reduce exposure to respiratory emissions of others.[3,5]
Approval	U.S. National Institute for Occupational Safety and Health (NIOSH) for N95 or similar and EU standards for FFP equivalents.[6] The Government of Canada lists other approved alternatives to N95s.	FDA with grading based on the level of resistance to splashing (e.g., ASTM 1 – venous pressure; ASTM 2 – arterial pressure; ASTM 3 – high velocity splash).	Not approved for use in any healthcare setting; not tested to any standard of effectiveness. **Note:** Many procedure-type masks found in retail outlets may not be assessed to any approval standards, and would also be considered non-medical masks.
Advantages	Medical grade respirators can be effective against aerosol penetration. Can be reused and disinfected with precautions.	Some protection against contact transmission, are disposable and inexpensive. Fit testing is not required.	Inexpensive and can be made from household materials. Can act as a reminder to not touch face.[5] Can be reused and laundered.[7]
Disadvantages	Filtration efficiency for aerosols is only effective if properly fit tested. Some users may experience some reduction in comfort/breathability. Expensive and may be in short supply.	Less effective against smaller particles (e.g., 0.4-1.3 µm), looser fit than N95 respirators, and therefore more penetration via leaks.[8] Not recommended for reuse or disinfection for use in healthcare environments.	Variable performance for respiratory protection and breathability depending on the material and design.[9] They do not replace other protective measures (e.g., hand hygiene and distancing).[5,10]